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DEFINING CONDITION OF PRESSURE AROUND THE UNDERGROUND OPENING TRAPEZOIDAL IN SHAPE, SUBSTRUCTURED BY ANCHORS IN MULTILAYERED DEPOSITS INVESTIGATED BY THE METHOD OF FINAL ELEMENTS

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ABSTRACT

The computer program ADINA is used for the pressure analysis on the model of the underground opening, trapezoidal in shape in layers of lignite. An analysis was made before, during and after the setting of three and five anchors. The theory about pressure distribution for secondary and tertiary pressure condition in the roof and board sides of the opening by setting anchors has been proven. In order to check the result, test of pulling out anchors from the roof of the opening has been done. The examinations and research conducted at the level of obtained results show the efficiency of setting underground opening by using anchors where there are multilayered deposits of lignite. The results of the research provided in this paper can also be used for underground openings in different shapes in multilayered deposits.

Key words: *pressure conditions, multilayered deposits, substructure, anchor, ADINA*

INTRODUCTION

In the process of substructure of the underground opening, it is necessary to make an assessment of substructures which include the adequate choice of rock mass classification, but also other technical conditions that have to be explored in order to make a good project in the case of the choice of substructure. In applied rock mechanics, in the field of mining, planning includes the choice of specific objects and provides the investigation of rock mass behavior in the case of secondary pressure condition, by using equations of theoretical and applied rock mechanics.

The analysis of primary pressure condition by numerical methods, and also the analysis of secondary and tertiary pressure condition by the method of final elements, using the program package ADINA in conditions before, during and after the setting of anchors in the underground opening for multilayered deposits, give useful, efficient and legitimate solutions. The paper offers the following accurate graphical comparisons of the underground opening that is trapezoidal in shape (15th floor-TOH):

- MFE model with the specified board side conditions and the force without built-in anchors, and with three and five built-in anchor has been done,

- Display of pressure σ_z axial force in anchors after the excavation of profiles (roof) and setting 3 and 5 anchors has been given,
- Plastic deformations before and after building in 3 and 5 anchors have been displayed,
- Comparative display of plastic deformations before and after building in 3 and 5 anchors has been given,
- Comparative display of plastic flag (the indicator of the emergence of plastic deformation in Gauss points of elements) during the period before and after building in 3 and 5 anchors.

The results of the pull-out force of anchors have been considered and offered on the same model, but only from different positions of the anchor built in a roof vertically, or in a board side of the premise. The results consider the vertical shift and display the force intensity. The size of the forces and shifts have been presented and given in an adequate figure.

The primary research goal of this paper is a numerical justification of legitimacy and efficiency of the applied system model of setting the underground opening (in the case of the opening that is trapezoidal in shape) by using anchors where there are multilayered deposits in mining conditions of lignite deposits of "Kreka" [1].

KREKA COAL BASIN

Coal basin "Kreka" is a part of Tuzla's territory basin, situated in the south-western part of the city, between the southern slopes of the mountain "Majevica" and valley of "Spreča" river, covering an area of around 180 km^2, Figure 1, [2]. The whole basin is located in Tuzla Canton, and spreads to the areas of the municipalities including Tuzla, Lukavac, Kalesija and Živinice. "Kreka" coal basin is known for its layers of good-quality lignite with favourable balance of a chemical structure and the heating value, and is therefore especially convenient for incineration in thermal power plants and small combustion plants. Environmentally friendly fuel with low investments in removing harmful emissions which contains total sulfur <0,5%, flammable sulfur <0,2%, ash 10-27%), and with the lower heating value up to 13,000 kJ/kg.

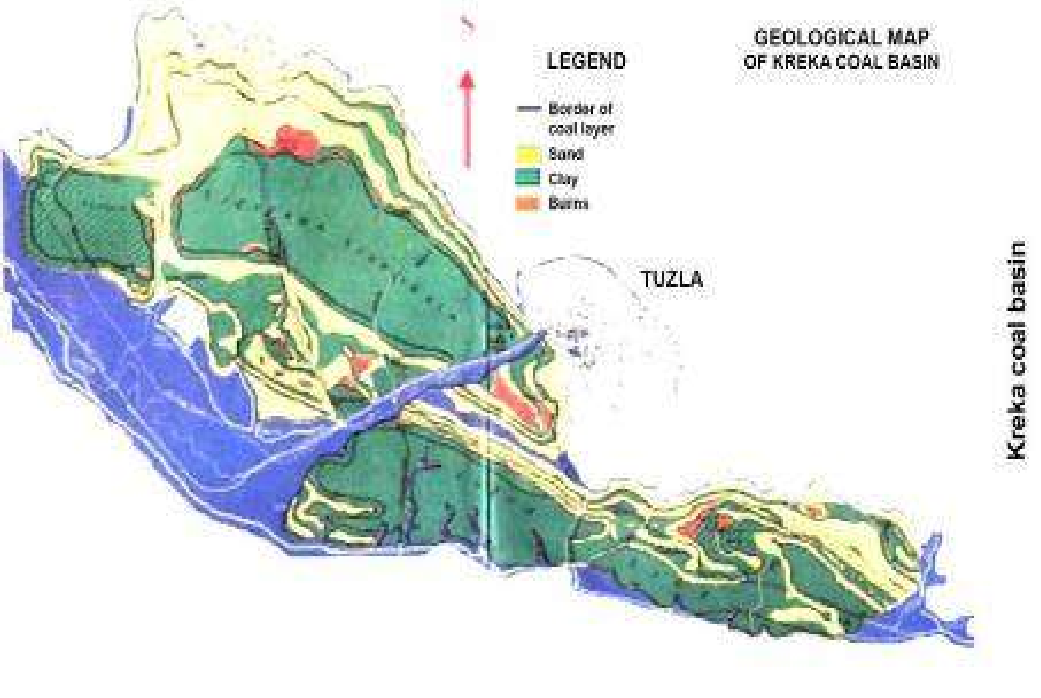


Figure1 Regional pattern of "Kreka" basin

There have been developed five lignite layers at this part of the basin, of different economic significance, and their development has been shown in the geological-stratigraphic column, which completely coincides with lithostratographic development of overall “Kreka” basin in general. “Kreka” coal basin consists of two geological units: the northern synclinorium with four, and the southern synclinorium with five lignite coal layers of lower Pliocene (pont) age, Figure 2, [3].

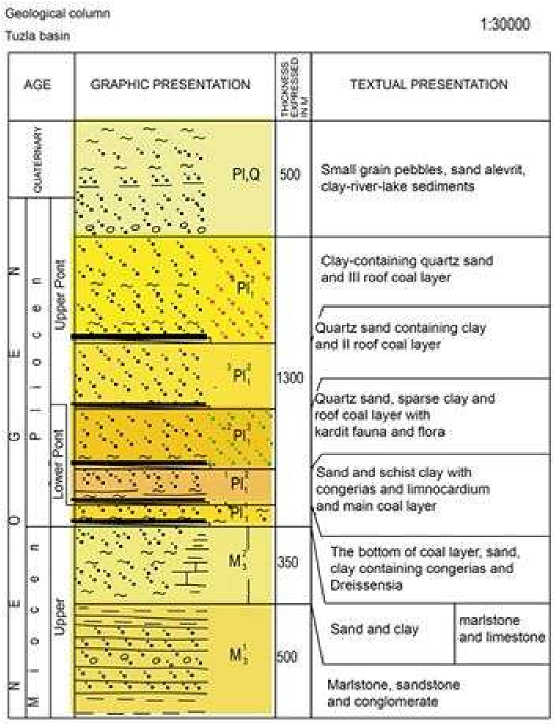


Figure 2 Geological-stratigraphic column of “Kreka” syncline

The main structural form that dominates the area of the northern synclinorium is the Kreka syncline with four coal layers: bottom of coal layer, the main layer, top of coal layer I, top of coal layer II. In the Kreka syncline, the mine “Mramor” in Mramor is active, and it exploits the main coal layer. The second-largest structural form of the northern synclinorium is “Lukavačka syncline”. There is an active open-pit mine Šikulje in Lukavac located in the area of this syncline that exploits top of coal layer I and top of coal layer II [4].

In the southern synclinorium, there are five lignite coal layers: bottom of coal layer, the main layer, top of coal layer I, top of coal layer II, top of coal layer III. The most significant of all formed tectonic units is “Dubravska syncline” with an active open-pit mine “Dubrave” in Dubrave that exploits the main and top of coal layer I.

THE ANALYSIS OF THE CONDITION OF PRESSURE AROUND THE UNDERGROUND OPENING IN THE COAL LAYERS BY THE METHOD OF FINAL ELEMENTS

ADINA (Automatic Dynamic Incremental Nonlinear Analysis) is a commercial finite element analysis program package which has widespread usage in industry and academic community, since it is suitable for the analysis of pressure in solid rocks (2D and 3D models) of different structures [5].

In this paper, 8.6 version has been used, and it shows the difference in the rearrangement of pressure between the unsubstructured opening and the opening substructured by anchors, i.e. it has shown secondary and tertiary pressure condition in a roof and board sides of the opening, which is the result of the anchor setting [6].

INPUT PARAMETERS OF THE WORK ENVIRONMENT

Input parameters of the work environment for the analysis using the final element method include geomechanic characteristics of the work environment, lithologic structure in the area of the analysed opening, the geometry of the underground opening, unsubstructured or substructured by anchors, Table 1, [7].

Table 1 Geomechanic characteristics of Kreka's series

TOP OF CLAY LAYER	COAL LAYER I	COAL LAYER II	COAL LAYER III	BOTTOM OF SAND LAYER
γ = 21 kN/m^3	γ = 12 kN/m^3	γ = 12 kN/m^3	γ = 13kN/m^3	γ = 1,70 kN/m^3
υ = 0,40	υ = 0,21	υ = 0,22	υ = 0,22	υ = 0,35
C =0,07 MPa	C =3,5 MPa	C =3,2 MPa	C =3,0 MPa	C =30 MPa
φ= 22^o	φ = 30^o	φ = 30^o	φ = 30^o	φ = 35^o
σ_z =0,02 MPa	σ_z =,1,4 MPa	σ_z =1,3 MPa	σ_z =1,20 MPa	σ_z =0 MPa
E = 25 MPa	E = 600 MPa	E = 600 MPa	E = 600 MPa	E = 300 MPa

In Figure 3, there is a structure profile of the coal layer, including the position, type and shape of the underground opening which is in the focus of this research and substructure. There are also all the necessary and available geomechanic characteristics of the coal layer and the accompanied deposits for the revir "Marići" for the 15th floor (TOH). This data have been used in the paper as the base for all modeling.

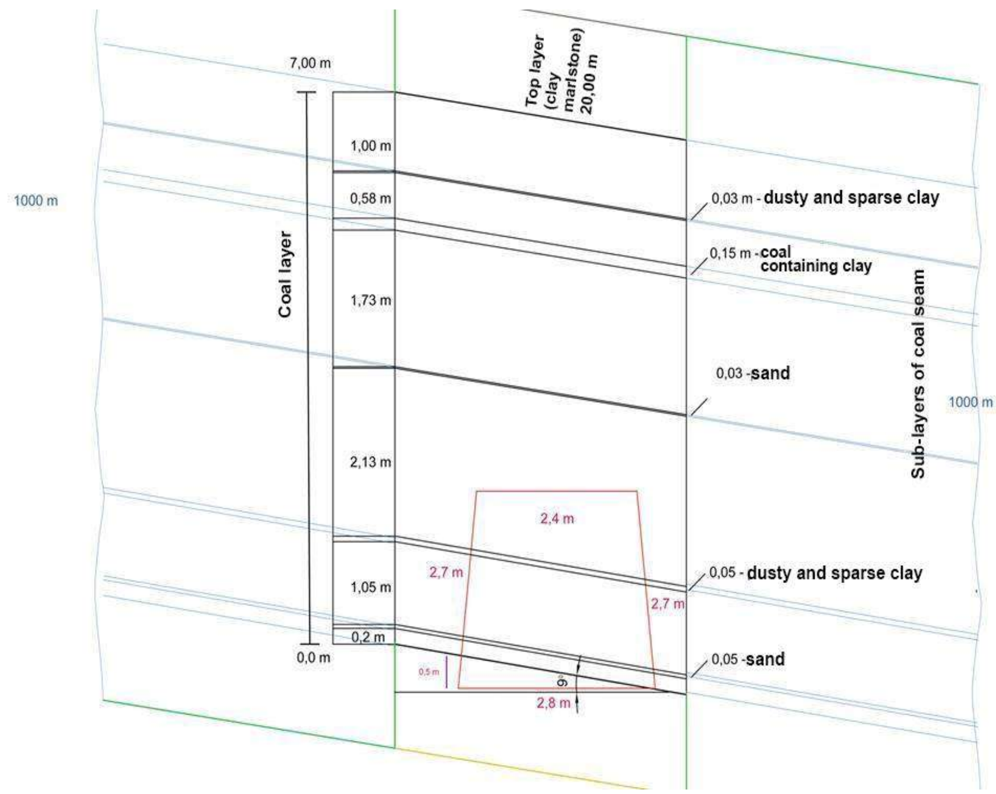
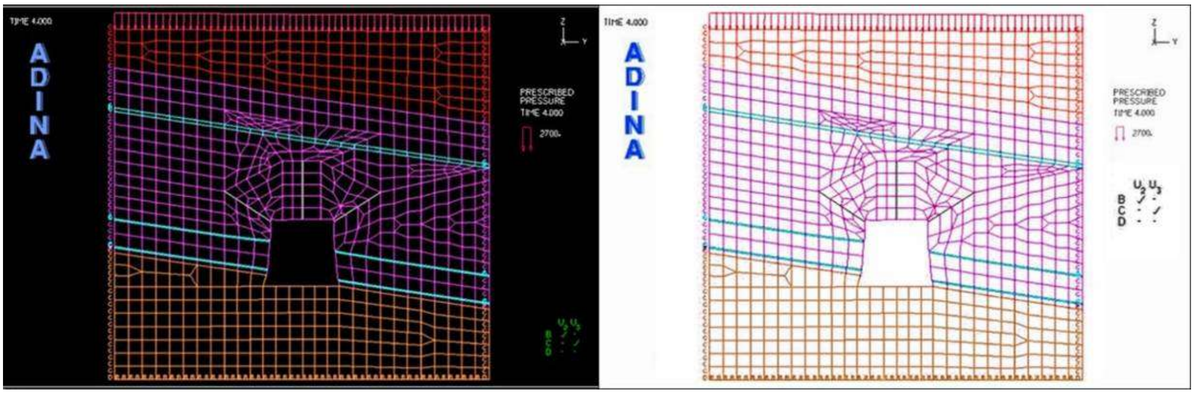


Figure 3. Structure profile for the trapezoidal shape of the opening for (TOH-15th floor)

The analysis has been conducted on two geologic cases. The first case is for the substructure of the opening trapezoidal in shape by 3anchors, and the second is by 5 anchors.

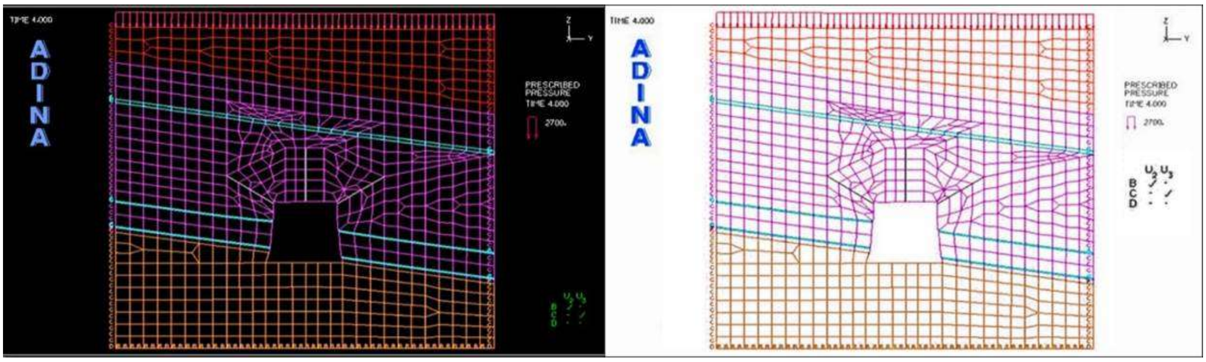
CASE 1:

MFE model with the modified board side conditions and the force of three built-in anchors for the underground opening trapezoidal in shape



CASE 2:

MFE model with the specified board side conditions and the force of five built-in anchors for the underground opening trapezoidal in shape



The figure in the first case shows the model of final elements for the opening trapezoidal in shape with built-in anchors, the position of lithologic members and display of board side conditions. The model contains 2960 nodes, with 963 quadrilateral elements, which represent the massif modeled by Mohr-Coulomb fracture condition and anchors of 14 generalized line elements. In the second case, the model contains 2960 nodes with 963 quadrilateral elements which represent the massif modeled by Mohr-Coulomb fracture condition and anchors of 23 generalized line elements.

DISPLAY OF PRESSURE Σ_Z AND AXIAL FORCE IN ANCHORS

The condition of the vertical pressure, i.e., the range of intervals from the minimal to maximal value of pressure, is given in the Figure 4 and expressed in kN/m^2. Minus sign means pressure (-), while plus sign (+) means bracing.

The display of vertical pressure around the opening highlights the rearrangement of pressure in massif. The force in anchors suggests that the middle anchor has the greatest force intensity and takes greater force. Also, a detail of axial force display which affects anchors is given. In the display, the pressure is expressed on the upper side, while on the lower side the bracing is given and expressed in kN. Practically speaking, in the case of the underground opening trapezoidal in shape, pressure is suppressed in massif, and what is fetched is out of the contour of the opening.

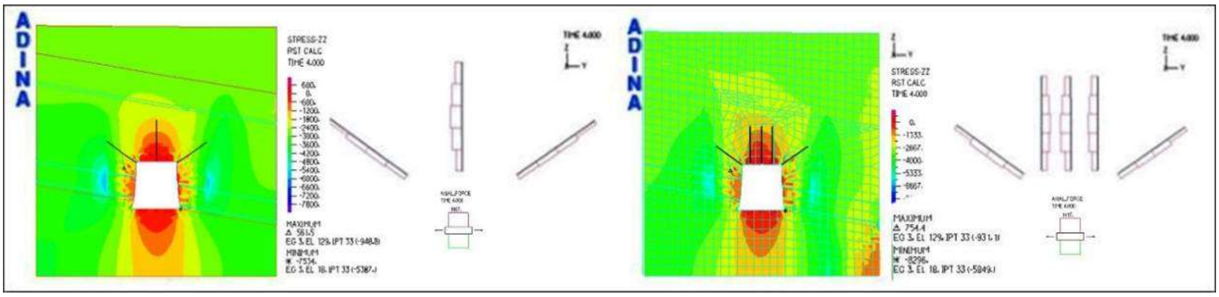


Figure 4 Display of pressure σ_z axial forces in anchors after the excavation of profiles with 3 and 5 anchors

PLASTIC DEFORMATIONS, VERTICAL SHIFT, PLASTIC FLAG

The extent of plastic deformations is of less intensity around the opening with built-in anchors. Plastic deformations are especially noticeable in the bottom right corner of the opening, which is the consequence of the lithologic composition and the shape of the opening where the sand is in the bottom part, and also because sharp corners cause high concentration of pressure. Plastic deformations are expressed in percentages (%). It is noticeable from Figure 5 that the extent of plastic deformations for the opening without anchors is of less intensity around the trapezoidal opening with 3 built-in anchors. It is also noticeable that there is an increase in the intensity of plastic deformations in the lower part of the opening, and the zone of plastification in the case of 5 anchors is reduced regarding the same case with 3 built-in anchors.

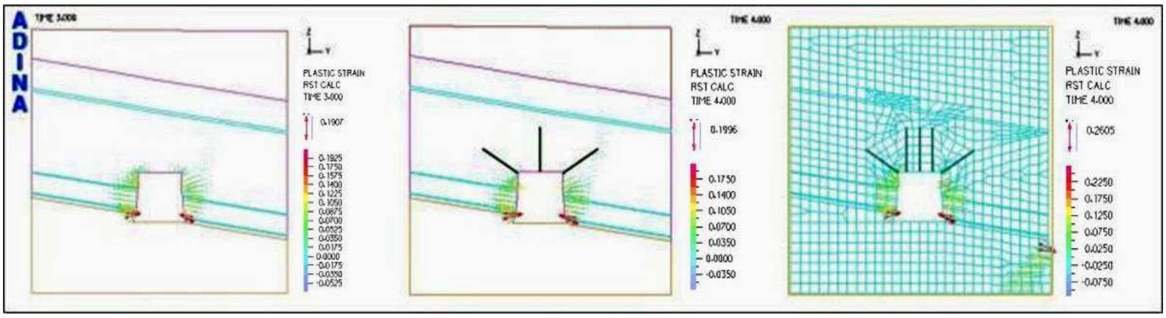


Figure 5 Comparative display of plastic deformations before and after building in 3 and 5 anchors

Vertical shifts offer an illustrative example when it comes to usage of anchors, since building in anchors in the short time of constructing the opening has a significant effect on the reduction of the height of the opening. It is noticeable from the illustration of comparative display of vertical shifts before and after building in 3 and 5 anchors that there is the change of scope of excavation to secondary pressure condition in the massif, and the changes of secondary pressure conditions in the massif after building in anchors. Altogether, it has been proved that building in anchors has a significant effect on the rearrangement and intensity of vertical shifts in the nearby side of the opening.

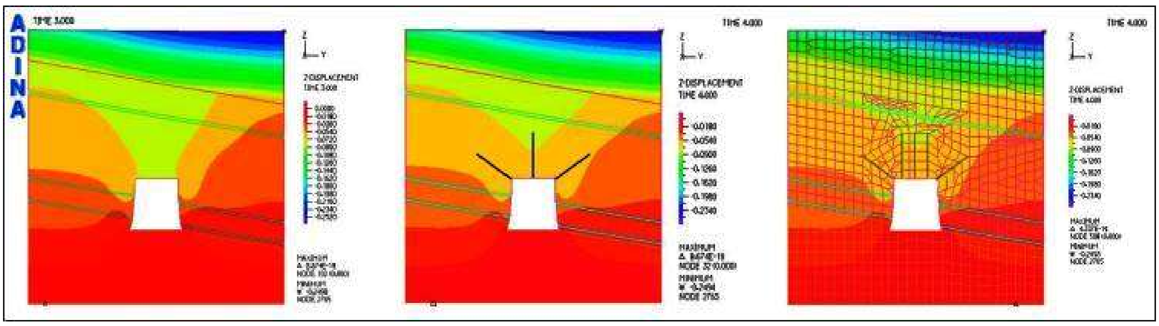


Figure 6. Comparative display of vertical shifts before and after building in 3 and 5 anchors

Plastic flag is the indicator of the emergence of plastic deformation in Gauss points of elements. It indicates tones and elements that have been affected by plastic deformation. It is noticeable from the legend that plastification occurred as the consequence of overflow of Mohr-Coulomb fracture condition. Also, the legend explains on which models plastic deformation can or has to be expressed due to bracing or overflow of Mohr-Coulomb fracture condition and it also shows that there is an evident difference between the case with 3 and the case with 5 anchors.

Plastic flag is especially noticeable in the opening without anchors, and it is noticeable in the right corner that plastification occurred due to bracing. Overflow of Mohr-Coulomb fracture condition is noticeable in the right side of the illustration, i.e., in the opening with built-in anchors. Building in three anchors in the trapezoidal shape of the underground opening significantly reduces the zone of plastification in the roof of the opening. The zone of plastification in the roof is eliminated by building in five anchors.

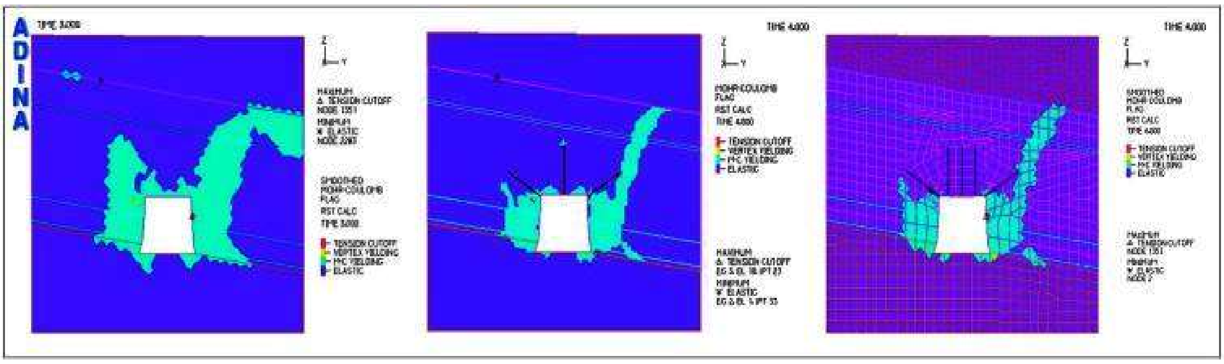


Figure 7. Comparative display of plastic flag during the period before and after building in 3 and 5 anchors

PULL-OUT FORCE

The results of the pull-out force of anchors have been considered and offered on the same model, but only from different positions of the anchor built in a roof vertically, or in a board side of the opening. The results consider the vertical shift and display the force intensity. The pull-out force of the roof anchor has been modeled. The size of the forces and shifts have been presented and given in adequate figures. What is evident is that the pull-out force is greater in the case of anchors built in a roof vertically than in the case of anchors built in a roof in a board side of a roof.

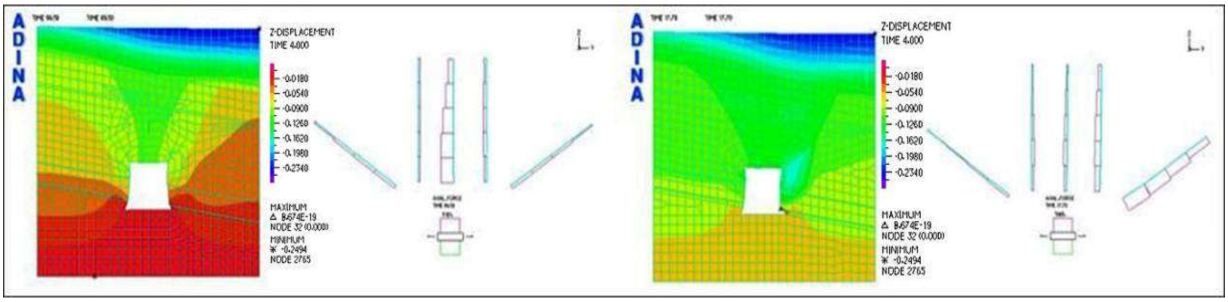


Figure 8. The pull-out force of the anchor set in a roof

CONCLUDING EXAMINATIONS

Based on the obtained results, it can be concluded that in the Mramor lignite mine, on the analysed profile of the trapezoidal shape of the underground opening for the 15th floor (TOH-15), there is an evident difference in rearrangement of pressure in case of the substructure using three anchors and the substructure using five anchors. The analysis of the pressure condition around the underground openings is a safe method for the choice of substructuring the underground openings by anchors. The pressure analysis has been conducted by numerical methods using the licensed software ADINA, version 8.6 at the Faculty of Mining, Geology and Civil Engineering. Model ADINA, in the engineering sense, gives reliable results, which offers a reliable perspective on the pressure and force of anchors. Through the software analysis of pressure, the thesis about rearrangement of pressure for the secondary and tertiary pressure condition in the roof and board sides of the opening by setting anchors had been proved, which is supported by the obtained results.

The force of pull-out obtained from the modeled value has to be considerably lower than the force of practical pull-out, because in this case the support is formed with the support of a pump and temporarily built-in support, which gives a bigger value of the pull-out force than modeled force.

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